Tradeoffs during the mission planning of SWOT

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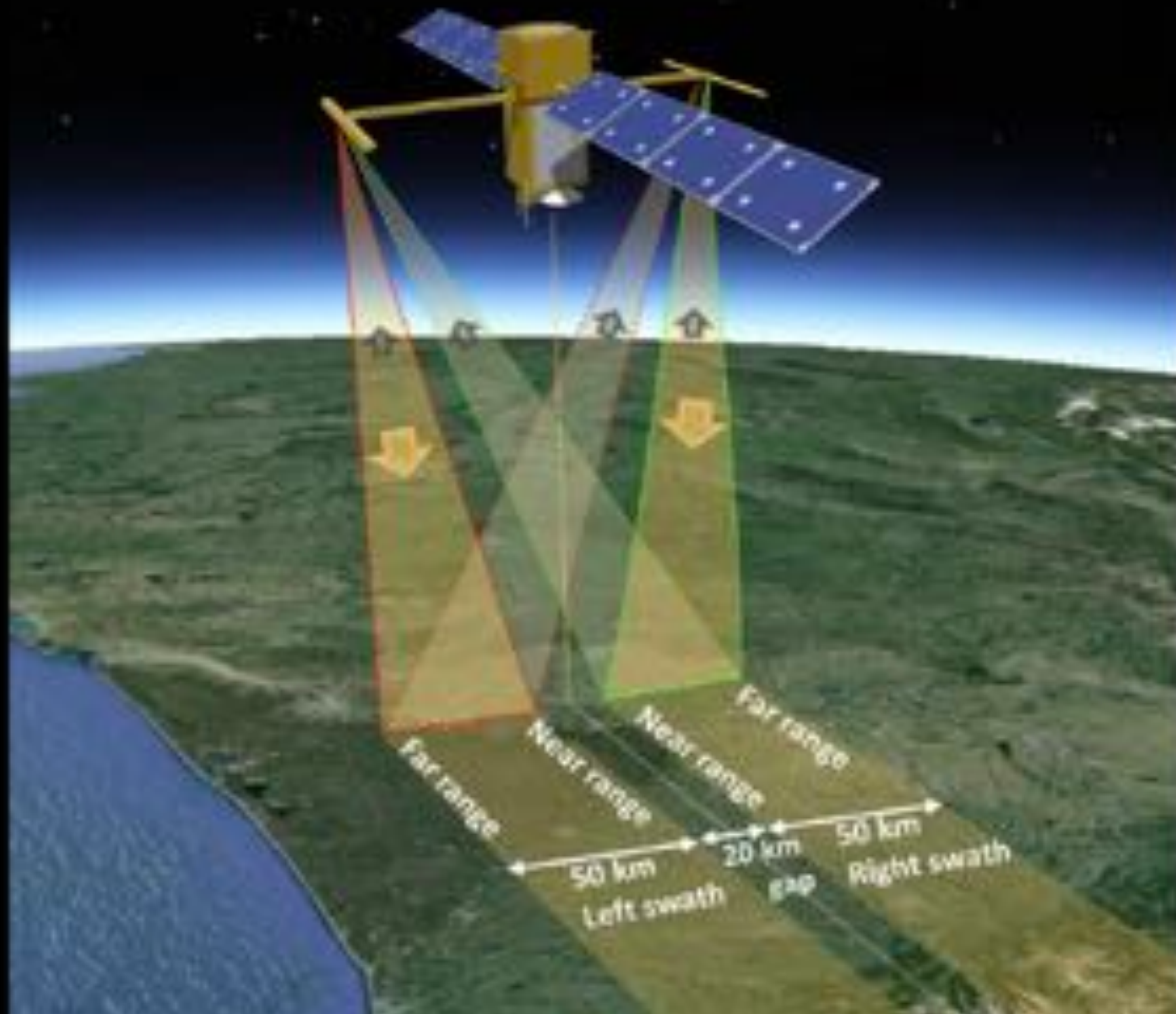
SnowEx Workshop • BWI • September 17, 2019

The Surface Water and Ocean Topography Mission

swot.jpl.nasa.gov



Biancamaria, Lettenmaier, and Pavelsky, *SoG*, 2016

The principal payload on SWOT is a Ka-band Radar Interferometer (KaRIn) operating at 35.75 GHz (8.6 mm) with twin 50 km swaths pointing 1-4.5° off nadir.

- 21-day repeat orbit at 890 km.
- Scheduled for launch in 2021
- 3 year nominal mission lifetime.
- Native azimuth resolution of 5.5 m
- Native range resolution of 60 m to 10 m
- Simultaneously measures inundation extent and water surface elevation
- Total budget: ~$1.1B

Courtesy Tamlin Pavelsky, UNC

SWOT will measure lake storage change and estimate river discharge globally

Simplified Timeline

- 2000-2004: NASA Surface Water Working Group
- Selection of a mission concept (InSAR): ~2004
- Partnership with oceanography for Decadal Survey proposal: ~2005
- 2007: Tier 2 of Decadal Survey & partnership with the French
- Pre-Phase A “Mission Concept Review” September 2012.
- Science Definition Team and AirSWOT experiments: 2014-2016
- Science Team 1: 2016-2020
- Launch scheduled for October 2021

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Selection of a mission concept: ~2004

- In 2004 there were multiple mission concepts to measure river and lake height, including interferometric synthetic aperture radar (InSAR) and Lidar

- There was a 2004 meeting where multiple engineering teams pitched the Surface Water Working Group (SWWG) then led by Doug Alsdorf on the technologies

- InSAR came out ahead, at that time, and became the leading contender for the mission, and the technology submitted to the 2007 Decadal Survey by the SWWG

- While some were in favor of Lidar, and were disappointed, the community picked a workable strategy and moved forward

Sometimes a community needs to pick something and move forward

- Dennis Lettenmaier expressed as a response to the SnowEx science plan that we ought to pick something and move forward

- Instead of picking a single instrument, what if we pick a collaborative approach where we invest time and energy in synergistic approaches: modeling, and assimilation and multiple instruments?

- Picking a synergy approach allows us to start strategizing about which pieces we need and how to move them forward.

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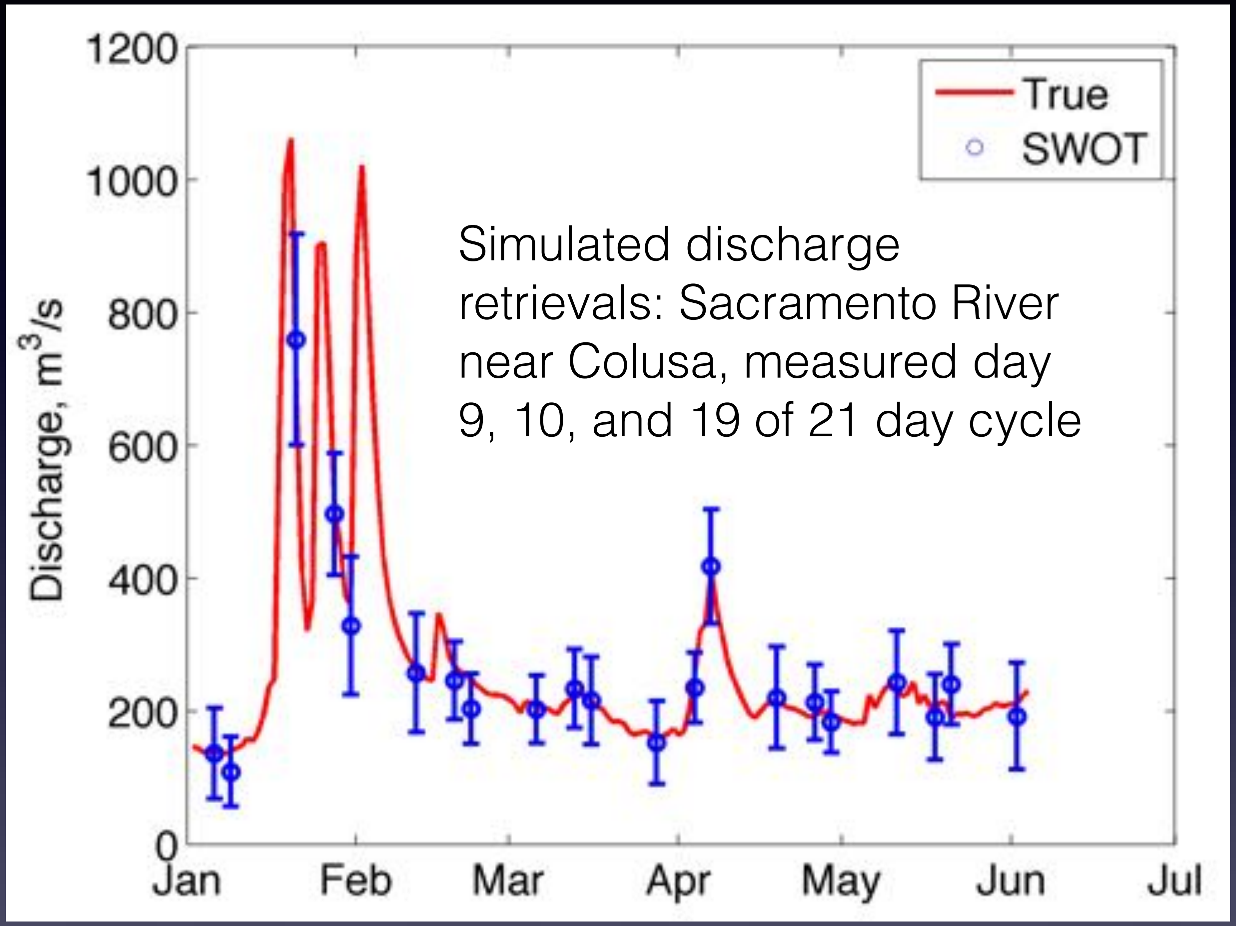
Partnership with Oceanography: The Orbit

- Both oceanography and hydrology submitted Ka-band InSAR to the DS
- The remote sensing of oceanography community is far more mature than surface water, with space borne missions dating to SeaSat (1978)
- The oceanography partnership was possible because hydrologists were willing to compromise on the orbit. Hearing of willingness to work together, the DS committee merged them.
- Despite compromise, the SWOT orbit still allows addressing global hydrological science questions e.g. at monthly time scale



SWOT can measure rivers down to 50-100 m in size. The SWOT orbit allows us to catch some but not all temporal dynamics. On average we are unbiased for flow at monthly scale [*Biancamaria et al.* 2010].

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Partnership with CNES: Spacecraft power

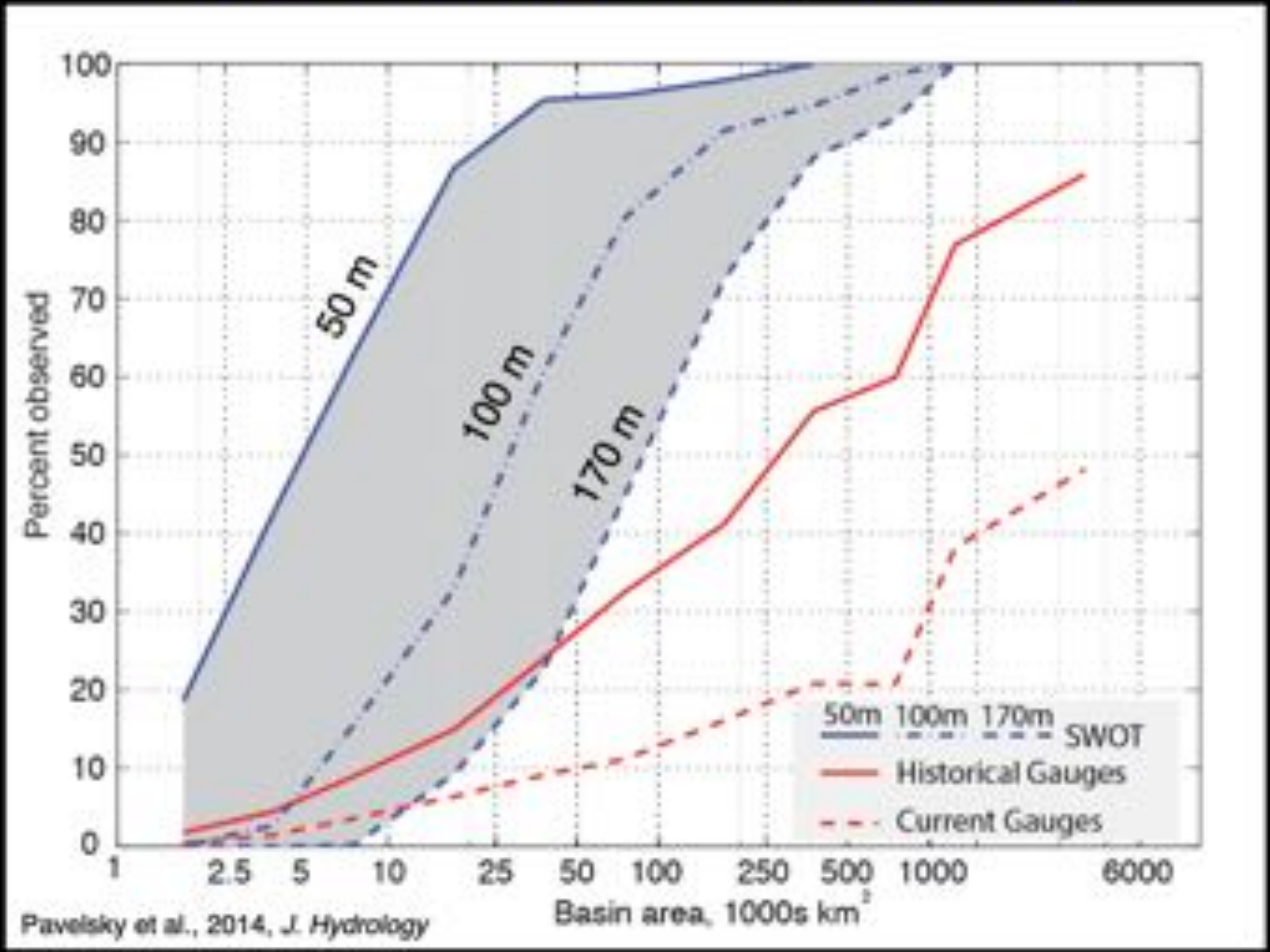
- Partnership between NASA and the French space agency CNES is long-standing for oceanography, e.g. TOPEX/Poseidon, launched in 1992. Canada (CSA) and UK are also partners.

- French partnership in SWOT was agreed upon in 2007. France is covering something like 20% of the total SWOT mission cost.

- This has been wonderful on the hydrology side, as it doubles the size of the community to work on algorithms, and brings new perspectives

- It can also lead to limitations, although these sometimes have silver linings. E.g. spacecraft power.

SWOT River Coverage Globally



Globally, SWOT will likely improve monitoring of rivers, especially for river basins between 25,000 and 250,000 km².

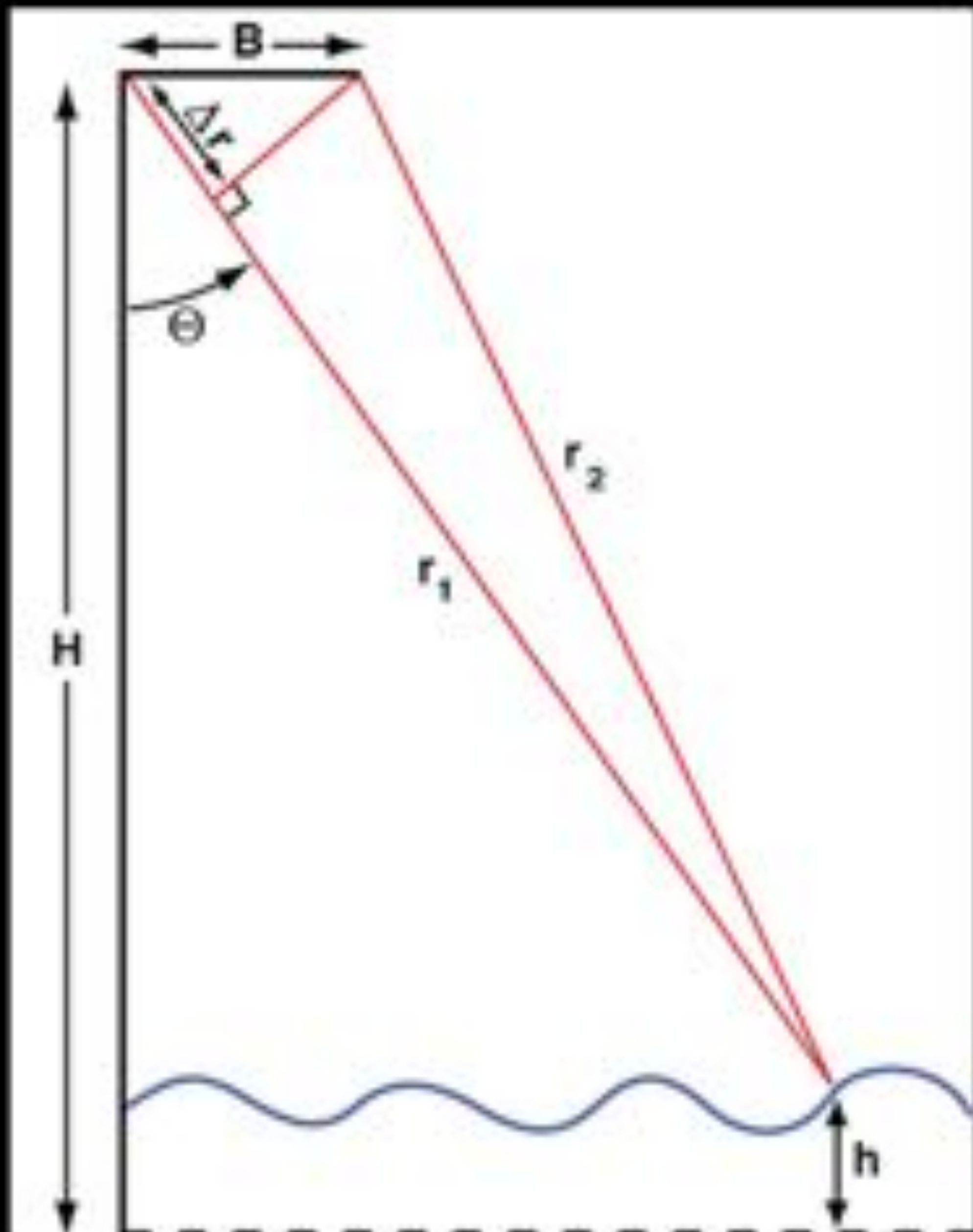
We have chosen to take a pragmatic approach and focus on observing 100 m wide rivers and larger (data is all kept, but algorithms adapted for wider rivers). Can't always optimize.

Mike’s Thoughts

- Seek an achievable, globally-relevant science target, and a strategy, and let’s move forward with it
- Don’t optimize. Compromise.
- Let’s keep international and interdisciplinary partners in mind and think opportunistically and creatively
- It does not seem we have one technology that can do everything. Is this as an opportunity to work together across many different sensing technologies and advance assimilation and modeling strategies?

Backup

Interferometric Measurement Concept



Slide Courtesy Ernesto Rodriguez, JPL

- Conventional altimetry measures a single range and assumes the return is from the nadir point
- For swath coverage, additional information about the incidence angle is required to geolocate
- Interferometry is basically triangulation
  - Baseline B forms base (mechanically stable)
  - One side, the range, is determined by the system timing accuracy
  - The difference between two sides (Δr) is obtained from the phase difference (Φ) between the two radar channels (λ is the radar wavelength).

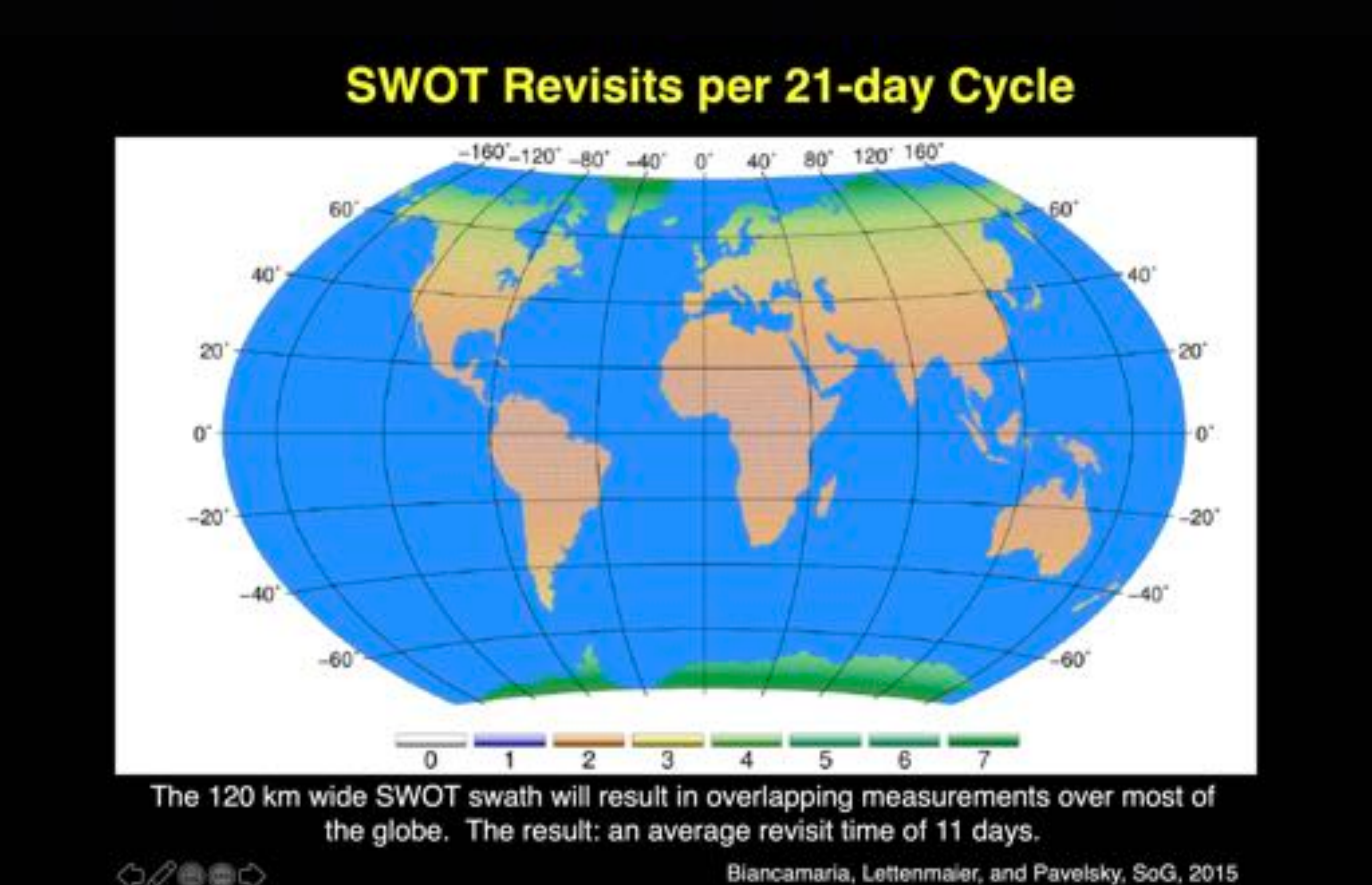
$$\Phi = 2\pi \, \Delta r/\lambda = 2\pi B \sin \Theta/\lambda$$

$$h = H - r \cos \Theta$$

Observation: The fundamental SWOT observable is water elevation and extent. This leads directly to ocean science targets, and directly to lake science targets, and not too complex to get to river science.

Surface Water Hydrology Science Questions

1. What is the spatial distribution of freshwater storages and runoff through rivers, lakes, and reservoirs? Does inclusion of the knowledge "close" water budgets of regional/global hydrology and climate models?
2. What are the impacts of water impoundments in reservoirs and natural lakes, human water withdrawals, and trans-boundary rivers on the global water cycle, societal water supply, and global sea level rise?
3. What are the regional-to-global-scale responses of lake volumes and river flows to climatic phenomena, e.g. droughts, floods, and a warming Arctic?
4. What are the three-dimensional forms of waves propagating through natural river channels, and how may these be used to improve hydrodynamic models of flood hazard and risk?
5. What are the spatial and temporal dynamics of water storage in millions of unmapped lakes and river floodplains, and how do they impact biogeochemical fluxes of carbon, nutrients, and greenhouse gases, waterborne diseases/public health, sediment transport, and ecosystem functioning?



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Simulated Raw SWOT Observations